

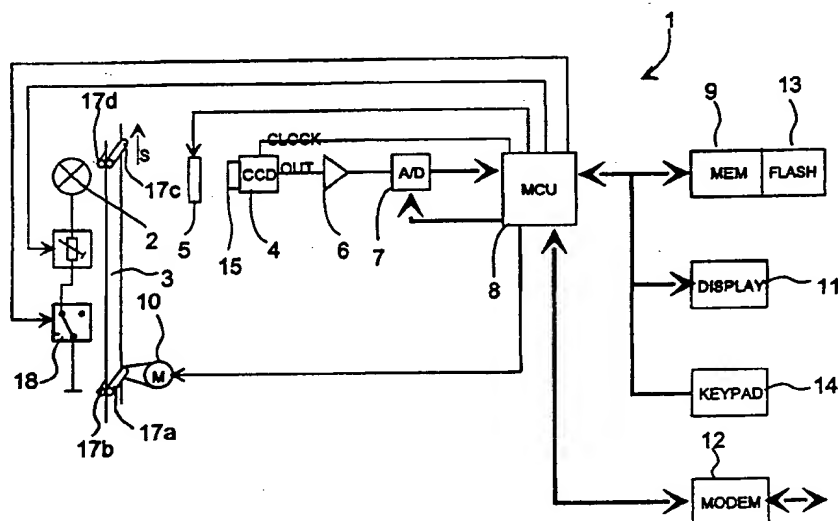
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(54) Title: DIGITIZING APPARATUS



(57) Abstract

The invention relates to a digitizing apparatus (1) for forming (digitizing) a digital, electrical image of a subject (3). The digitizing apparatus (1) comprises a light sensor (4) consisting of one or several photosensitive picture elements (P1, P2, ..., P10) and to which the image of the subject (3) is arranged to be directed in one or several parts, the image being divided into pixels. Each picture element (P1, P2, ..., P10) to be used in digitizing is arranged to conduct a photoelectric conversion to generate a signal proportional to the lightness of the pixel directed to the picture element. At least one pixel to be digitized is arranged to be subjected to at least two conversions. In at least two different conversions, the quantity of light to be directed during the conversion of said pixel to the picture element conducting the conversion is arranged to be adjustable, wherein in at least two conversions, the quantities of light are unequal.

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## Digitizing apparatus

5 The present invention relates to a digitizing apparatus for forming a digitized image of a subject, as presented in the preamble portion of the appended claim 1. The digitizing apparatus comprises photosensitive picture elements to which the image of the subject is arranged to be directed in one or several parts, the image being divided into pixels, wherein each picture element to be used in digitizing is arranged to  
10 conduct a photoelectric conversion to form a signal proportional to the lightness of the pixel directed to the picture element. The digitizing apparatus is intended particularly for digitizing films to an electrical format. Furthermore, the invention relates to a method for forming a digitized image, as presented in the preamble portion of the appended  
15 claim 14.

Several digitizing apparatuses have been developed, in which a film or a corresponding image of a subject is digitized by using a known photosensitive sensor. For this purpose, *e.g.* a CCD sensor (charged  
20 coupled device) is applicable, consisting typically of several photosensitive picture elements arranged either in the form of a line (line sensors) or a matrix (image sensors). Light induces in each picture element a charge whose quantity depends on *e.g.* the intensity of the light as well as the time of action in the picture element, *i.e.* the exposure  
25 time. Such digitizing apparatuses are equipped with optics whereby the image of the subject to be digitized is directed to the picture elements of the CCD sensor. Using a sufficiently large matrix image sensor, it is possible to convert the whole image area with one exposure. Instead, when a line sensor is used, the image is formed *e.g.*  
30 line by line, wherein after digitizing each line either the subject or the CCD sensor is usually moved so that the next line can be digitized. Consequently, the image of the subject formed by digitizing is a kind of set of pixels in matrix form, each representing a certain part of the subject of the image. The accuracy of the digitized image is affected particularly by the number of pixels, *i.e.* the resolution of the digitized  
35 image. This resolution can be affected *e.g.* by selecting a photosensitive sensor with a sufficient number of picture elements.

Also known are CCD sensors developed particularly for colour video cameras (colour light sensors), where the conversion means conducting the photoelectric conversion of one pixel consists of three picture elements (CCD elements). The picture elements PR, PG, PB of the conversion means are arranged *e.g.* side by side or in a triangular shape. These alternative placements of the picture elements PR, PG, PB are shown in a reduced manner in the appended Figures 3c and 3d. Each conversion means is provided with colour filters for red, green and blue light so that in each conversion means, a red filter is provided in front of one picture element PR, a green filter is provided in front of a second picture element PG, and a blue filter is provided in front of a third picture element PB. The red filter transmits primarily rays of light having their wavelength in the range of red light, wherein the corresponding picture element PR generates a charge corresponding to the intensity of red light. In a corresponding way, the green filter transmits green light and the blue filter transmits blue light, wherein the intensities of these colours can be measured from the corresponding picture elements PR, PG, PB.

Consequently, the charge of each CCD picture element depends on the intensity and exposure time of light directed to it. This charge can be transmitted in a way known as such to the output of the CCD sensor, from which this can be measured as a voltage value. From the output of the CCD sensor, the information of each pixel is obtained advantageously in sequence, *i.e.* in serial form. These pixel-specific voltage values are converted by an analog/digital converter to digital form, wherein this digital numerical value can be stored *e.g.* in the memory of a control unit.

One use for such a digitizing apparatus is to digitize x-ray films, wherein x-ray films converted into digital form can be *e.g.* filed electrically, and if necessary, they can also be easily and quickly transmitted even long distances. Known digitizing apparatuses, however, have *e.g.* the drawback that in x-ray films, the optical density (OD), indicating the capacity to transmit the intensity of light in a logarithm, for different pixels can vary in a considerable range, typically from 0 to 6. Thus, for achieving a sufficient resolution in digitizing, an analog/digital converter must be used which has a sufficiently high resolution capability, in the order of

19 bits. However, such analog/digital converters are very expensive, thereby raising the cost of these digitizing apparatuses considerably. Another problem is the fact that with high optical density, *i.e.* in dark spots of the film, the basic noise of the CCD sensor interferes significantly with the digitizing of such a pixel and may distort the measuring result. This can be reduced for example by increasing the exposure time or by raising the intensity of the illuminator, but thus the resolution will be degraded in bright spots, correspondingly.

European patent EP 239 936 presents an apparatus in which two image scans are used for digitizing an image. The first scan is used to determine *e.g.* whether the subject is in text form or involves a grey scale. Furthermore, in connection with the first scan, the threshold values are selected, on the basis of which different grades of grey are identified in the case that the subject involves a grey scale. The apparatus disclosed in said patent publication divides the subject of the image in parts, wherein the apparatus first examines whether said part contains a text or images, and on the basis of this selects the algorithm and threshold values for each time. However, this apparatus does not eliminate the problem that an analog/digital converter with a high resolution has to be used to achieve good resolution in bright and dark parts of the image.

Japanese patent application JP 8 079 461 presents a system for image digitizing, wherein a CCD sensor is used for scanning an image, and the exposure time of the sensor is adjusted during scanning of the image. The exposure time is adjusted so that during the first scan, a reset time is calculated for each picture element in the CCD sensor. During the examination, the CCD sensor is moved at a slower rate, and in the second phase, the CCD sensor is moved faster, utilizing the pre-calculated reset times in this phase. With the apparatus presented in the publication, the signal noise ratio is improved. However, the apparatus presented in the publication is relatively slow, due to *e.g.* the fact that the image is scanned twice and even at different speeds. On the other hand, this requires precise focusing of the CCD sensor in both scanning phases to ensure that the reset times to be calculated really correspond to that part of the image which is to be actually digitized in

the second phase. Also this apparatus does not give a good resolution in dark and light spots without a high-resolution analog/digital converter.

5 It is one purpose of the present invention to provide an improved method and an apparatus for forming (digitizing) a digital, electric image of a subject, particularly in view of the dynamics as compared with prior art. The invention is based on the idea that the digitizing is conducted by using two or more conversions, and that different luminosities are used in each conversion *e.g.* by adjusting the intensity of the illuminator. The image of the subject can be preferably divided into pixels. For each pixel, the final digitizing result is calculated preferably on the basis of values measured in the different conversions. The digitizing apparatus according to the present invention is characterized in that at least one pixel to be digitized is arranged to be subjected to at least two conversions, and that in at least two different conversions, the quantity of light to be directed during the conversion of said pixel to the picture element conducting the conversion is arranged to be adjustable, wherein in at least two conversions, the quantities of light are unequal. The method of the present invention is characterized in that at least one pixel to be digitized is subjected to at least two conversions, and that in at least two different conversions, the quantity of light to be directed during the conversion of said pixel to the picture element conducting the conversion is arranged to be adjustable, wherein in at least two conversions, the quantities of light are unequal.

25 The present invention gives considerable advantages. Using a digitizing apparatus according to the invention, it is possible to digitize also subjects where variations in luminance at different points are very great, still producing a good digitizing result at each point. According to a first embodiment of the invention, the digitizing apparatus is also relatively quick, because different exposure phases for each pixel are conducted without moving the subject or the image sensor between these exposure phases. Thus, different exposure phases are accurately directed to the same pixel, whereby the quality of the digitized image can be further improved.

The digitizing apparatus according to the invention can be implemented with an analog/digital converter with a smaller resolution than would be

possible by using currently known digitizing apparatuses, to obtain the same resolution in the whole image area. This is a factor that makes the digitizing apparatus less expensive, because the prices of analog/digital converters rise very sharply with increasing resolution. Moreover, in the digitizing apparatus of the invention, the signal-noise ratio can also be improved, which also improves the quality of the digitized image.

- 5                    Fig. 1            shows a digitizing apparatus according to a first advantageous embodiment of the invention in a reduced block chart,
- 10
- Fig. 2            shows the optics of the digitizing apparatus according to the first advantageous embodiment of the invention in a skeleton diagram,
- 15
- Fig. 3a          shows the division of the subject of the image into pixels in a reduced manner,
- 20                  Fig. 3b          is a skeleton diagram on an advantageous light sensor,
- Fig. 3c          is a skeleton diagram on an advantageous colour light sensor,
- 25                  Fig. 3d          is a skeleton diagram on another advantageous colour light sensor,
- Fig. 3e          shows an example on conversion results of the digitizing apparatus for scanning one line,
- 30
- Fig. 4            shows a dimmer that can be used in connection with a digitizing apparatus according to the first advantageous embodiment of the invention,
- 35                  Fig. 5            shows a digitizing apparatus according to a second advantageous embodiment of the invention in a reduced block diagram,

Fig. 6 shows the optics of a digitizing apparatus according to the second advantageous embodiment of the invention in a skeleton diagram,

5 Fig. 7 shows a digitizing apparatus according to a third advantageous embodiment of the invention in a reduced block diagram, and

10 Fig. 8 shows an advantageous example of the radiation pattern of an emitter and sensitivities of picture elements.

### EXAMPLE 1

15 A digitizing apparatus 1 according to a first advantageous embodiment of the invention is presented in the block diagram of Fig. 1. The digitizing apparatus consists of an illuminator 2, which is preferably a fast controllable illuminator, such as a light emitting diode (LED) or a xenon tube. This fast controllability gives the advantage that the luminosity of the illuminator can be quickly adjusted to a desired level, and thus different exposure phases can be conducted consecutively without long delays between the different exposure phases. This factor will be described in more detail below in this specification.

25 Light rays from the illuminator 2 are directed through a subject 3, such as a film, to a light sensor 4, which is preferably a CCD sensor (charge coupled device). The travel of the light rays is controlled optically *e.g.* with lenses 15 and possibly with mirrors (not shown) in a way known as such. The example of Fig. 2 presents one optical solution to place the illuminator 2, the subject 3 and the light sensor 4. It is obvious for any-  
30 one skilled in the art that the optics can be implemented with a variety of different solutions which are feasible for implementing the digitizing apparatus 1 of the invention.

35 In the digitizing apparatus 1 according to the first embodiment of the invention, shown in Fig. 1, the light sensor 4 used is a so-called line sensor, *i.e.* the light sensor 4 consists of several CCD picture elements installed in a line.

Figure 3b is a skeleton diagram on an advantageous CCD light sensor 4 consisting of picture elements P1, P2, ..., P10, such as CCD picture elements, arranged in the form of a line. These picture elements P1, P2, ..., P10 constitute the photosensitive part of the light sensor, *i.e.* the part conducting the photoelectric conversion. The number of the picture elements corresponds preferably to the resolution (separating capacity) that is required for digitizing the subject 3 in one direction, for example in the horizontal direction (X axis in Fig. 3a). Consequently, the digitizing of the entire subject 3 can thus be completed line by line; in other words, after the digitizing of each line in the X direction, either the subject 3 or the light sensor 4 is moved in the Y direction (Fig. 3a) preferably to the next line, as is known as such.

At each exposure time, the light sensor 4 is exposed to rays of light passed through the subject 3 for a certain time, after which a shutter 5 is closed, preventing the entry of light rays in the light sensor 4. At this stage, a charge is generated in the CCD picture elements P1, P2, ..., P10 of the light sensor 4, the quantity of the charge being proportional to the quantity of light directed at the CCD picture element. The quantity of light is affected by the brightness of the illuminator, losses and linearity errors in the optics, the brightness of the pixel directed at the CCD picture element in question, and the exposure time.

The quantity of light to be directed to the CCD sensor can be adjusted also with a dimmer 16, one example of the dimmer 16 being shown in Fig. 4. In this case, the dimmer consists of two dimmer blocks 16a, 16b, which may have different light transmission capacities. One dimmer block 16 can also be bright, whereby it does not limit the quantity of light. With this solution, it is not necessary to adjust the brightness of the illuminator 2.

The charges of the CCD picture elements can be read from the output line OUT of the light sensor 4 in a way known as such, *e.g.* by pulses entered in a clock line CLOCK, whereby in connection with each pulse, the charge of one CCD picture element is transmitted in the output line OUT. Consequently, information is obtained from the light sensor 4 of this example in serial form. The quantity of the charge is indicated as a voltage in the output line OUT, and this voltage can still be amplified, if

necessary, with a voltage amplifier 6, the amplified voltage signal being transferred from the output of the voltage amplifier 6 to an analog/digital converter 7 to be digitized. The analog/digital converter 7 generates a digital message proportional to the voltage, *e.g.* a binary digit of 16 bits.

5 For example, at a voltage value 0, the binary digit is 0, and correspondingly, at a voltage value of *e.g.* 5 V, the binary digit is 65,535. The control unit 8 of the digitizing apparatus, *e.g.* a micro controller unit MCU, reads this binary digit from the output of the analog/digital converter 7 and stores it in a memory 9, preferably a random access memory RAM.

10 This way the control unit 8 reads the quantity of the charge of each CCD picture element and stores the corresponding digital number in the memory 9 where a storage location is reserved for the numerical value corresponding to the charge of each CCD picture element.

15 Next, the control unit 8 adjusts the luminosity of the illuminator 2 for example 8-fold. After this, the control unit 8 opens the shutter 5, whereby rays of light can enter the light sensor 4. After the exposure time, the control unit 8 closes the shutter 5, after which the control unit 8 reads again the charge of each CCD picture element and transfers the numerical values corresponding to the charges to the memory 9. These values, corresponding to the second brightness setting of the illuminator and converted into digital form, are stored preferably at a different location than the values corresponding to the first brightness setting of the light source, whereby both sets of values can be used for calculating the final digitizing result. The second numerical values do not necessarily need to be stored, if the final digitizing result for each pixel is calculated immediately after the first exposure.

30 For example, after digitizing of one line, the control unit 8 starts a motor 10 that moves the subject 3 in a way that the next line of the subject to be digitized can be directed to the light sensor 4. The example of Fig. 2 shows rolls 17a—17d, whereby a film is moved in the direction of arrow S. After this, said two exposures are taken again, and the digitized values are read into the memory 9. Following this, the subject is moved again for digitizing the next line. The above-mentioned steps are repeated as long as the whole area of the subject that is to be digitized is scanned and the digitized value of each pixel of each area of the subject to be digitized is formed with different luminosities. At this

stage, according to an advantageous embodiment of the invention, the digitized values corresponding to each pixel with these different luminosities are stored in the memory 9 of the digitizing apparatus.

5 It is also possible to move the film continuously, provided that a conversion can be made of the area of each pixel. For example, in a photoelectric conversion arranged in a line form, one pixel line can be digitized fast.

10 The next step is to calculate the final digitizing result for each pixel. Let us assume that the binary digit formed by the analog/digital converter 7 is very close to zero at such pixels which are very light, *i.e.* the luminosity directed at the CCD picture element is high. In a corresponding manner, the conversion result of the analog/digital converter 7 is close  
15 to maximum, which with a 16 bit converter thus corresponds to the numerical value of 65,535, in dark spots of the pixel. Thus, the luminosity directed at the CCD picture element is small. In practice, scanning with a smaller luminosity means that the dark details of the subject cannot be differentiated, because the conversion result is the maximum or very  
20 close to it. However, scanning with the highest intensity allows a larger luminosity to enter the CCD picture elements also in the dark details, whereby the binary numerical values generated are generally smaller than said maximum value. In a corresponding manner, for bright details of the subject 3, a better resolution is achieved by using a smaller luminosity. This is due *e.g.* to the fact that when exposing with a greater  
25 luminosity, the analog/digital converter 7 gives the minimum, *i.e.* zero, as the conversion result, irrespective of small variations in the brightness of the pixel of the subject, but with a smaller luminosity, slightly greater conversions results are obtained.

30 Figure 3e shows still another example of said conversion results for scanning one line. The pixels of the line are, in general, relatively dark, but at some pixels, (pixels *ca.* 4000—4500), there is a brighter spot. Also in the dark parts, there are slight variations in darkness, which are  
35 shown as ridges in a curve B indicating the conversion results with greater quantity of light. The curve B also shows that with this greater quantity of light, the conversion result of the brightest details is zero substantially for all values, and no differences in brightness between

different pixels are distinguishable in this spot. A curve A indicates scanning with a smaller intensity, whereby in the dark details, the conversion result amounts to the maximum and differences are not formed between variations in darkness in the dark spots. However, in the pixels of the brighter spot the conversion result is greater than 0, and the conversion result is affected by variations in brightness of the bright spots. Consequently, the dynamics of the digitizing apparatus 1 according to the invention has been increased in a simple way, and it is still possible to use an inexpensive analog/digital converter 7. If the corresponding dynamics were obtained by using only one exposure, the requirement in this example case would be to use an analog/digital converter of at least 19 bits, which is significantly more expensive than a 16 bit analog/digital converter. In such a 19 bit A/D converter, also problems with noise, particularly at dark details, are greater than in digitizing with the digitizing apparatus according to the invention.

The final digitizing result is formed on the basis of digitized values calculated from these two scans. This can be conducted *e.g.* in a way that for those pixels, where the conversion result of scanning conducted with smaller intensity, *i.e.* smaller quantity of light directed to the picture element, is the maximum or close to the maximum, a greater weight is given to the result of conversion with higher intensity, *i.e.* greater quantity of light directed to the picture element, and, in a corresponding way, for those pixels, where the conversion result of scanning conducted with greater intensity is the minimum or close to the minimum, a greater weight is given to the result of conversion with lower intensity. For other pixels, *e.g.* both conversion results are utilized with a suitable weighting.

The final digitizing result can be presented *e.g.* on a display means 11 in the digitizing apparatus in the form of an image, for example as a monochrome image or a colour image, whereby different colours can be used to emphasize those details in the image which are very bright or very dark.

The conversion result can also be transferred in electric form *e.g.* by means of a modem 12 to a telecommunication network or another communication network. Furthermore, the conversion result can be

stored e.g. on a diskette (not shown) or a so-called FLASH memory circuit 13 for example for filing.

5 In this context, one advantage of the invention should be mentioned, namely that the sensitivity of the CCD sensor increases more in proportion than an increase in the quantity of light, whereby the conversion results are also more accurate in a corresponding way.

10 Furthermore, the block diagram of Fig. 1 shows a keypad 14 whereby the operation of the digitizing apparatus 1 can be controlled, and if necessary, it is possible to select e.g. the number of exposures and the luminosity to be used at each exposure time.

15 In the digitizing apparatus 1 according to a first advantageous embodiment of the invention, presented above, two different scans were used, but it is also possible to apply the invention by using three or even more scans with different luminosities, whereby the conversion results from these different exposures determine the final digitizing result for each pixel.

20 If necessary, the exposure time can be changed for different exposures. Moreover, a shutter 5 is not necessary, but the illuminator 2 can also be turned off for the time of reading the charges of the light sensor 4. However, it is advantageous to keep the light sensor 4 dark for  
25 the time of this reading, thereby preventing cross talk from the CCD picture elements.

30 Furthermore, the invention is not limited solely to a light sensor 4 in the line form, but it is also possible to use a light sensor in the matrix form, whereby the whole image area can be exposed at one exposure time and after this, the CCD picture element of each light sensor 4 is read respectively, as presented above. This is followed by a second exposure by using a different luminosity, and after this exposure, the charges generated by the light sensor 4 are read again. This method  
35 has the advantage that the subject 3 or the light sensor 4 does not need to be moved during digitizing of the subject 3. Moreover, the resolution of the analog/digital converter 7 is not limited to 16 bits but also other resolutions can be used according to the application.

Within the scope of the invention, the digitizing apparatus 1 can also be implemented in a way that two or several samples are taken from the area of each pixel, and the subject 3 can be slightly moved between  
5 each sampling time, if necessary. Thus, only a part of the area of the pixel is directed to each CCD picture element at each sampling time. It is also possible to use a more accurate light sensor 4 so that there are two or more CCD picture elements at each pixel, whereby the conversion result for the pixel is formed from the information given by these  
10 picture elements.

## EXAMPLE 2

A digitizing apparatus 1 according to a second advantageous embodiment of the invention is shown in the reduced block chart of Fig. 5. The digitizing apparatus 1 consists of an illuminator 2 comprising e.g. one or  
15 several light diodes LED or a xenon tube.

Rays of light emitted from the illuminator 2 are conducted through a  
20 subject 3, such as a film. The light rays transmitted through the film are directed optically, e.g. with lenses (not shown) to a mirror 20 partly permeable to rays of light. This partial light permeability gives the advantage that the quantities of light are different for the light passed through the mirror 20 and for the light reflected from the mirror 20 in the  
25 case that the light transmitting capacity is substantially different from 0.5. The permeability is for example 10 %, which in this specification indicates that ca. 10 % of the light rays are passed through the mirror 20 and ca. 90 % of the light rays are reflected from the reflecting surface of the mirror 20. In practical mirrors, some of the light rays are  
30 scattered and some are absorbed onto the surface of the mirror. These losses can, however, be taken into account advantageously at the stage of calibration of the digitizing apparatus 1.

The rays of light that are passed through the mirror 20 are conducted to  
35 a first light sensor 4a, and the rays of light that are reflected from the reflecting surface of the mirror 20 are conducted to a second light sensor 4b. The light sensors 4a, 4b are advantageously CCD sensors. The travel of light rays is controlled optically e.g. with lenses 15 and possibly

with other mirrors (not shown) in a way known as such. The example of Fig. 6 shows another optical solution for placement of the illuminator 2, the subject 3 and the light sensors 4a, 4b. It will be appreciated by anyone skilled in the art that the optics can be implemented in a variety of solutions for implementing the digitizing apparatus 1 according to the invention.

Also in this digitizing apparatus 1 according to the second embodiment of the invention, shown in Fig. 5, the light sensors 4a, 4b used are line sensors. At each time of exposure, the light sensors 4a, 4b are subjected for a certain time to rays of light that have passed through the subject 3. This exposure time is adjusted either by controlling the illuminator directly on/off, or with a shutter 5, whereby it is opened for starting the exposure and closed after a predetermined exposure time. After the exposure, a charge is generated in the CCD picture elements P1, P2, ..., P10 of the light sensor 4a, 4b, the quantity of the charge being proportional to the quantity of light directed to the CCD picture elements.

The charges of the CCD picture elements can be read from the output line OUT1, OUT2 of the light sensor 4a, 4b by a method known as such, e.g. in the following way. Let us assume that the charges of the light sensors are measured alternately so that the charge of the first picture element of the first light sensor 4a is read at first, the charge of the corresponding picture element of the second light sensor 4b is read next, the charge of the second picture element of the first light sensor 4a is read after this, etc. The control unit 8 of the digitizing apparatus generates clock pulses which are lead to a clock line CLOCK1 in the first light sensor, whereby in connection with each pulse, the charge of one CCD picture element is transferred to the output line OUT1. The quantity of the charge is shown as a voltage in the output line OUT1. A first voltage amplifier 6a amplifies the voltage corresponding to the charge, wherein the output of the first voltage amplifier 6a has a voltage proportional to the charge. The amplified voltage signal is transferred to a first analog/digital converter 7a. The first analog/digital converter 7a generates a digital message proportional to the voltage, such as a binary digit of 16 bits. For example, at the voltage value 0, the binary digit is 0, and in a corresponding manner, at the voltage value of e.g. 5 V, the binary digit is 65,535. The control unit 8 of the digitizing apparatus,

for example a micro controller unit MCU, reads this binary digit from the output of the first analog/digital converter 7a and stores it in a memory 9, preferably a random access memory RAM.

5 Next, the control unit 8 of the digitizing apparatus generates clock pulses in a clock line CLOCK2 of the second light sensor, for transferring the charged state of the picture elements to the output line OUT2 of the second light sensor. The voltage signal is amplified in a second voltage amplifier 6b, and the amplified voltage signal is digitized in a  
10 second analog/digital converter 7b. The control unit 8 reads the digital value, which is thus proportional to the charge of the picture element of the second light sensor 4b, and stores the numerical value in the memory 9. In this way, the control unit 8 reads the quantity of the charge of each CCD picture element in both light sensors 4a, 4b and stores the  
15 corresponding digital value in the memory 9. The memory 9 advantageously has a memory location reserved for the numerical value corresponding to the charge of each CCD picture element in the both light sensors 4a, 4b. Because the luminosities directed to the first light sensor 4a and the second light sensor 4b from the same pixel are unequal,  
20 also the digitizing results are unequal. The way of utilizing these unequal luminosities in the digitizing apparatus according to the invention will be described further below in the specification.

For example after digitizing one line, the control unit 8 starts a motor 10  
25 for moving the subject 3 so that the next line to be digitized can be directed at the light sensor 4a. The example of Fig. 2 shows rolls 17a—17d, whereby a film is moved in the direction of arrow S. After this, the charged states of the picture elements in the light sensors 4a, 4b are measured as described above, and the digitized values are read into  
30 the memory 9. Following this, the subject is moved again for digitizing the next line. The above-mentioned steps are repeated as long as the whole area of the subject that is to be digitized is gone through and the digitized value for each pixel of each area of the subject to be digitized is formed with different luminosities. At this stage, according to an advantageous embodiment of the invention, the digitized values corresponding to each pixel with these different luminosities are stored in the  
35 memory 9 of the digitizing apparatus 1.

In the next phase, the final digitizing result is calculated for each pixel. Let us assume that the binary digit generated by the analog/digital converter 8 is close to zero for those pixels that are very light, *i.e.* the quantity of light directed to the CCD picture element is large. Correspondingly, the conversion result of the analog/digital converter 8 is close to the maximum, which with a 16-bit converter thus corresponds to the numerical value of 65,535, in dark spots of the pixel. Thus the quantity of light directed to the CCD picture element is small. In this advantageous embodiment of the invention, shown in Fig. 5, the intensity of the rays of light that have passed through the mirror 20 is smaller than the intensity of the rays of light that have been reflected from the mirror 20; consequently, the picture elements of the first light sensor 4a are subjected to a smaller luminosity than the picture elements of the second light sensor 4b. In practice, the measurement of quantities of light with the first light sensor 4a, conducted with a smaller luminosity, means that the dark details of the image cannot be distinguished, because in such spots the conversion result is the maximum or very close to the maximum. However, the measurement of quantities of light with the second light sensor 4b, conducted with a greater luminosity, allows the entry of a greater quantity of light to the CCD picture elements of the second light sensor 4b also in the dark details, wherein the binary digital values generated are, in general, smaller than said maximum value. In a corresponding manner, for the bright details of the subject 3, a better resolution is achieved with the first light sensor 4a than the second light sensor 4b. This is due *e.g.* to the fact that with exposure to a greater luminosity, the analog/digital converter 8 gives the minimum value, *i.e.* zero, as the conversion result, irrespective of small variations in brightness in the pixel of the subject, but with a smaller luminosity, slightly greater conversion results are obtained.

The solution presented above gives *e.g.* the advantage that a charged state obtained with two different intensities can be measured as precisely as possible in the area of the same pixel, which improves the reliability of the measurement. This is necessary particularly in such applications of the digitizing apparatus 1 according to the invention where the film is moved continuously.

The final digitizing result is formed on the basis of these digitizing values calculated from the measuring results of these two light sensors 4a, 4b. This can be conducted *e.g.* in a way that for those pixels, where the conversion result of the measurement conducted with a smaller intensity, *i.e.* with the first light sensor 4a, is the maximum or close to the maximum, a greater weight is given to the result of conversion with a higher intensity, *i.e.* the measurement conducted with the second light sensor 4b, and, in a corresponding way, for those pixels, where the conversion result of the measurement conducted with the second light sensor 4b is the minimum or close to the minimum, a greater weight is given to the result of conversion of the measurement conducted with the first light sensor 4a. For other pixels, *e.g.* both conversion results are utilized with a suitable weighting.

The final digitizing result can be presented *e.g.* on a display means 11 in the digitizing apparatus in the form of an image, for example as a monochrome image or a colour image, whereby different colours can be used to emphasize those details in the image which are very bright or very dark.

In the digitizing apparatus 1 according to the second advantageous embodiment of the invention, presented above, two light sensors 4a, 4b were used, but it is also possible to apply the invention by using three or even more light sensors with different luminosities, by using *e.g.* dimmers. The conversion results from these different exposures determine the final digitizing result for each pixel.

The shutter 5 is not necessary, but the illuminator 2 can also be turned off for the time of reading the charges of the light sensor 4a. However, it is advantageous to keep the light sensor 4a dark for the time of this reading, thereby preventing cross talk from the CCD picture elements. To control the illuminator 2, it is possible to use *e.g.* an electrically controllable switch 18, wherein advantageously the controller 8 turns the switch to the off-position for starting the exposure and to the on-position for terminating the exposure, correspondingly. The control signal used for the switch 18 is *e.g.* a logic signal whose voltage value in normal applications is in the first state (logical 0 state) *ca.* 0 V and in the second state (logical 1 state) *ca.* 5 V, which is known as such.

## EXAMPLE 3

5 A digitizing apparatus 1 according to a third advantageous embodiment of the invention is presented in the reduced block diagram of Fig. 7. The digitizing apparatus 1 consists of an illuminator 2 comprising two emitters 2a, 2b. The emitters consist of e.g. one or several light emitting diodes LED or a xenon tube. The radiation patterns of the emitters 2a, 2b differ from each other in that the range of the strongest radiation in the frequency spectrum is located differently, which is shown as different colours when the wavelength is in the range of visible light. In the digitizing apparatus 1 according to the invention, the first emitter 2a emits advantageously red light and the second emitter 2b emits advantageously green light. Thus, the ranges of the strongest radiation of the emitters 2a, 2b are sufficiently distant from each other. Moreover, the maximum intensities of radiation from the emitters 2a, 2b are different. However, the invention is not limited to such wavelengths of emitters, but within the scope of the invention, it is also possible to use also other wavelengths. Instead of two emitters 2a, 2b, it is also possible to use one emitter having a radiation pattern with e.g. two ranges of stronger radiation with unequal maximum intensities.

25 In the digitizing apparatus 1 according to a third advantageous embodiment of the invention, one light sensor 4 is used, which is advantageously a colour light sensor, and each converter means 19a, 19b, 19c comprises at least two, usually three picture elements PR, PG, PB. The light sensor 4 is advantageously a line sensor, i.e. it consists of converter means 19a, 19b, 19c placed in a line, wherein it is possible to digitize the pixels of one line of the subject 3 in one exposure.

30 Consequently, the subject 3 is illuminated with two illuminators 2a, 2b emitting light of different colours. The rays of light passing through the subject 3 are conducted to the light sensor 4 so that one pixel at a time is directed optically at one converter means 19a, 19b, 19c. Thus, the first picture element PR of the converter means, provided with a red filter transmitting light of the colour of the first illuminator 2a, measures the intensity of light rays passing through the pixel in the wavelength of red light. In a corresponding manner, the second picture element PG of

the converter means, provided with a green filter transmitting light of the colour of the second illuminator 2b, measures the intensity of light rays passing through the pixel in the wavelength of green light.

- 5 The charges of the picture elements are conducted via voltage amplifiers 6a, 6b to be digitized in analog/digital converters 7a, 7b. For this part, the operation of the apparatus according to the third embodiment of the invention corresponds to the operation of the apparatus according to the second embodiment of the invention, which was described  
10 above in this specification and to which reference is made in this context.

Furthermore, in the digitizing apparatus 1 according to the third advantageous embodiment of the invention, one alternative to implement the  
15 illuminator 2 can be to use one emitter 2a, which emits radiation with a maximum intensity which is advantageously close to the wavelength measured by one picture element PR, PG, PB of the converter means 19a, 19b, 19c of the light sensor, e.g. primarily in the wavelength of the first picture element PR measuring red light. Part of the radiation is also  
20 directed to the second picture element PG, but the radiation is of smaller intensity than the radiation directed to the first picture element, wherein the second picture element measures this suppressed radiation. Figure 8 shows an advantageous example of the radiation pattern of an emitter 2a and sensitivities of picture elements PR, PG for different wavelengths. A curve IS shows the intensity of radiation from the emitter 2a at different wavelengths  $\lambda$ . A curve IR shows the sensitivity of a first picture element PR for different wavelengths, and a curve IG shows the sensitivity of a second picture element PG for different wavelengths, respectively. From the curves, it can be seen that from  
25 the radiation emitted from the emitter 2a, the range of a greater intensity is in the sensitivity range of the first picture element PR and a small part of the radiation is in the sensitivity range of the second picture element PG. Thus, quantities of light from the same pixel can be measured with two different intensities. The square area of the range indicated with the reference A1 in Fig. 8 is proportional to the quantity of light measured with the first picture element PR, and correspondingly, the square area of the range indicated with the reference A2 is proportional to the quantity of light measured with the second picture ele-  
30  
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ment PG. The intensity and sensitivity curves presented above are only given as examples, but the invention can be applied also with different wavelength ranges.

5 This digitizing apparatus 1 according to the third advantageous embodiment of the invention gives *e.g.* the advantage that the optical structure can be made slightly simpler than by using two different light sensors 4a, 4b. At the same time, according to the invention, two digitizations are obtained with two different intensities, from which the final  
10 conversion result can be determined.

Within the scope of the invention, the digitizing apparatus 1 can also be implemented in a way that two or several samples are taken from the area of each pixel, and the subject 3 can be slightly moved between  
15 each sampling, if necessary. Thus, at each CCD picture element, only part of the area of the pixel is directed at each sampling time. It is also possible to use more precise light sensors 4a, 4b so that there are two or more CCD picture elements at one pixel, wherein the conversion result of the pixel is formed from the information obtained from these  
20 picture elements.

In the examples according to the second and third embodiments of the invention, presented above, two voltage amplifiers 6a, 6b and two analog/digital converters 7a, 7b were used; however, it is also possible  
25 to implement the digitizing apparatus according to the invention with only one voltage amplifier 6a and one analog/digital converter 7a, if the conversion rate is sufficiently high for the purpose. In such a solution, the charge states of the picture elements P1, P2, ..., P10 are thus measured consecutively, and *e.g.* a switch is used to transmit the  
30 charge of the desired picture element P1, P2, ..., P10 to a measuring circuit 6a, 7a, as will be obvious for anyone skilled in the art.

The invention is not limited solely to the embodiments presented above, but it can be modified within the scope of the appended claims.

Claims:

1. A digitizing apparatus (1) for forming (digitizing) a digital, electrical image of a subject (3), which digitizing apparatus (1) comprises a light sensor (4) consisting of one or several photosensitive picture elements (P1, P2, ..., P10) and to which the image of the subject (3) is arranged to be directed in one or several parts, the image being divided into pixels, wherein each picture element (P1, P2, ..., P10) to be used in digitizing is arranged to conduct a photoelectric conversion to generate a signal proportional to the lightness of the pixel directed to the picture element, **characterized** in that at least one pixel to be digitized is arranged to be subjected to at least two conversions, and that in at least two different conversions, the quantity of light to be directed during the conversion of said pixel to the picture element conducting the conversion is arranged to be adjustable, wherein in at least two conversions, the quantities of light are unequal.
2. A digitizing apparatus (1) according to claim 1, **characterized** in that the quantity of light is arranged to be adjustable by adjusting the brightness of an illuminator (2).
3. A digitizing apparatus (1) according to claim 1, **characterized** in that the quantity of light is arranged to be adjustable with a dimmer (16) placed between the subject (3) and the light sensor (4) and comprising at least two dimmer blocks (16a, 16b) with a different permeability to light.
4. A digitizing apparatus (1) according to claim 1, **characterized** in that the quantity of light is arranged to be adjustable with a dimmer (16) placed between an illuminator (2) and the subject (3) and comprising at least two dimmer blocks (16a, 16b) with a different permeability to light.
5. A digitizing apparatus (1) according to claim 1, **characterized** in that the quantity of light is arranged to be adjustable by adjusting exposure time.

6. A digitizing apparatus (1) according to claim 5, **characterized** in that the exposure time is arranged to be adjusted with a shutter (5) placed between the subject (3) and the light sensor (4).

5 7. A digitizing apparatus (1) according to claim 1, **characterized** in that the quantity of light is arranged to be adjustable by conducting a photoelectric conversion of at least one pixel to be digitized with at least two different picture elements (P1, P2, ..., P10, PR, PG, PB).

10 8. A digitizing apparatus (1) according to claim 1, **characterized** in that it comprises at least two light sensors (4a, 4b) with one or more picture elements (P1, P2, ..., P10) and at least one mirror (20) that is at least partly permeable to rays of light, wherein the quantity of light is arranged to be adjustable by directing an image of the subject (3) to the  
15 mirror (20) that is at least partly permeable to rays of light, from where the rays of light transmitted through the mirror (20) are arranged to be conveyed to a first light sensor (4a), and the rays of light reflected from the mirror (20) are arranged to be conveyed to a second light sensor (4b).

20 9. A digitizing apparatus (1) according to claim 8, **characterized** in that it comprises at least one light sensor (4) with at least one converter means (19a, 19b, 19c) consisting of two or more picture elements (PR, PG, PB), and an illuminator (2) which emits radiation whose frequency  
25 spectrum has at least two different maximum intensities, and that a first picture element (PR) is arranged to measure the quantity of light substantially in the wavelength of one intensity maximum and a second picture element (PG) is arranged to measure the quantity of light substantially in the wavelength of a second intensity maximum.

30 10. A digitizing apparatus (1) according to claim 9, **characterized** in that the illuminator (2) consists of two emitters (2a, 2b) which emit light in unequal wavelengths.

35 11. A digitizing apparatus (1) according to claim 8, **characterized** in that it comprises at least one light sensor (4) with at least one converter means (19a, 19b, 19c) consisting of two or more picture elements (PR, PG, PB), and an illuminator (2) which emits radiation whose frequency

spectrum has at least one intensity maximum, and that a first picture element (PR) is arranged to measure the quantity of light at a substantially different wavelength than a second picture element (PG).

5 12. A digitizing apparatus (1) according to any of the claims 1 to 11, **characterized** in that the part of the light sensor (4) conducting the photoelectric conversion is arranged to be kept substantially in dark between different conversion times.

10 13. A digitizing apparatus (1) according to any of the claims 1 to 12, **characterized** in that the subject (3) is a film, such as an x-ray film.

15 14. A method for forming (digitizing) a digital, electric image of a subject (3), the method using a light sensor (4) consisting of one or several photoelectric picture elements (P1, P2, ..., P10) and to which an image of the subject (3) is directed in one or several parts, the image being divided into pixels, wherein each picture element (P1, P2, ..., P10) to be used in digitizing conducts a photoelectric conversion to generate a signal proportional to the quantity of light of the pixel directed at the picture element (P1, P2, ..., P10), **characterized** in that in the method, at least one pixel to be digitized is subjected to at least two conversions, and that in at least two different conversions, the quantity of light to be directed during the conversion of said pixel to the picture element (P1, P2, ..., P10) conducting the conversion is arranged to be adjustable, wherein in at least two conversions, the quantities of light are unequal.

20 15. A method according to claim 14, wherein the signal generated by the picture element (P1, P2, ..., P10) and proportional to the quantity of light has a minimum value and a maximum value, the minimum value being smaller than the maximum value, **characterized** in that the conversion result of the pixel to be digitized is formed on the basis of different conversions so that if the conversion result in the conversion conducted with the smaller luminosity is in the maximum or close to the maximum, a great weight is given to the conversion conducted with the greater luminosity, and if the conversion result in the conversion conducted with the greater luminosity is in the minimum or close to the

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minimum, a great weight is given to the conversion conducted with the smaller luminosity.

- 5 16. A method according to claim 14, **characterized** in that in the method, at least one pixel to be digitized is subjected to a photoelectric conversion with at least two picture elements (P1, P2, ..., P10, PR, PG, PB).
- 10 17. A method according to claim 16, wherein the signal generated by the picture elements (P1, P2, ..., P10, PR, PG, PB) and proportional to the quantity of light has a minimum value and a maximum value, the minimum value being smaller than the maximum value, **characterized** in that the conversion result of the pixel to be digitized is formed on the basis of signals generated by different picture elements (P1, P2, ...,
- 15 P10, PR, PG, PB) so that if the signal generated by the first picture element (P1, P2, ..., P10, PR) is in the maximum or close to the maximum, a great weight is given to the signal generated by the second picture element (P1, P2, ..., P10, PG), and if the signal generated by the second picture element (P1, P2, ..., P10, PG) is in the maximum or
- 20 close to the maximum, a great weight is given to the signal generated by the first picture element (P1, P2, ..., P10, PR).

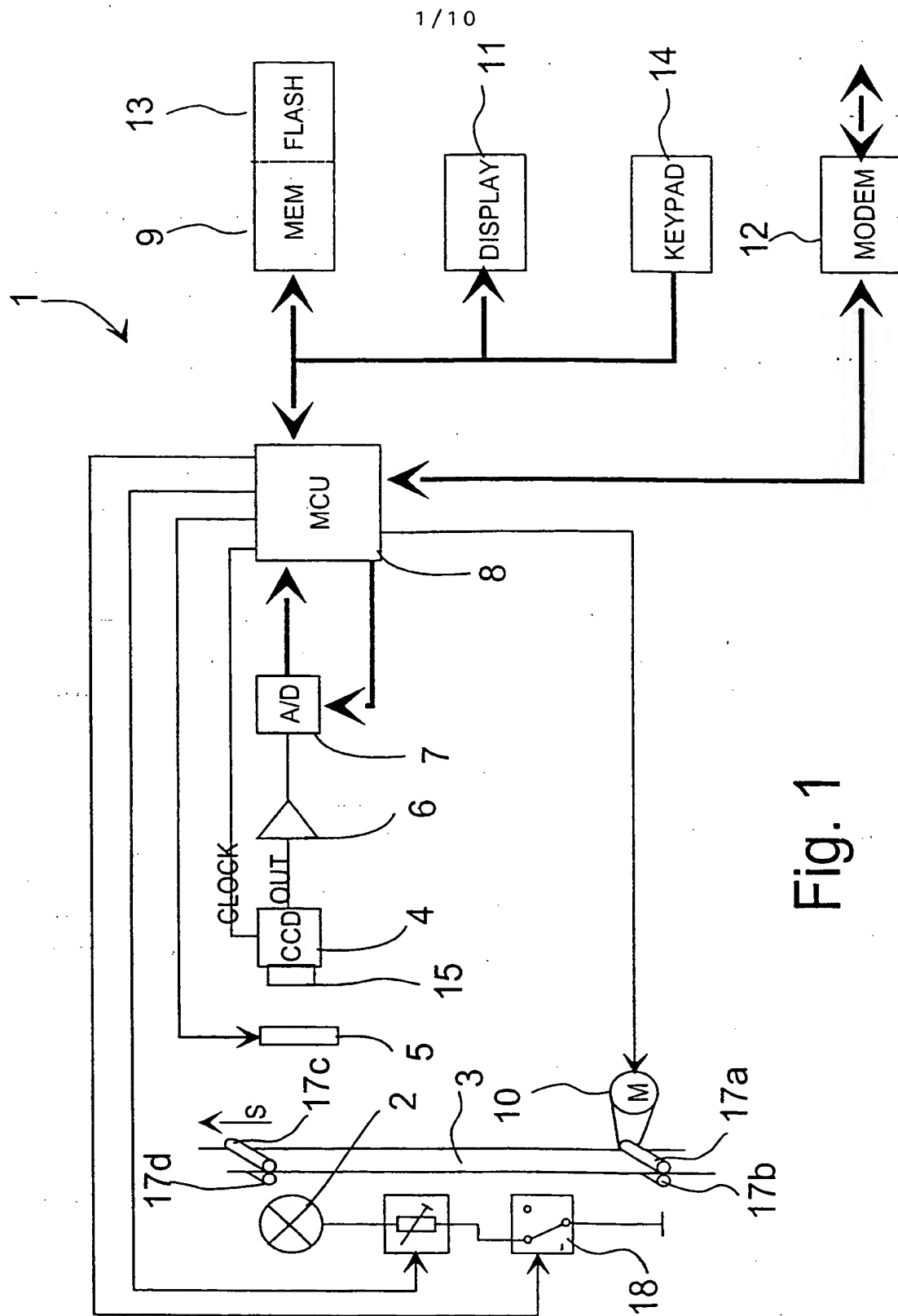


Fig. 1

2/10

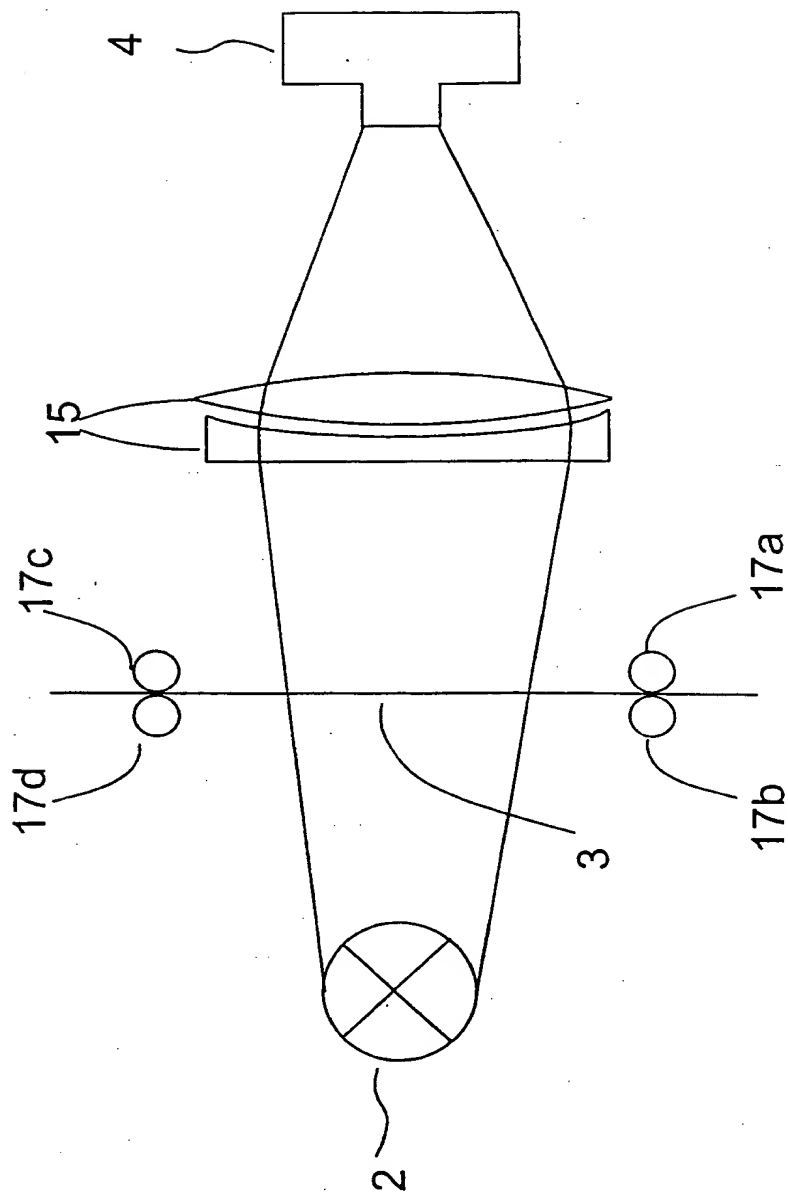


Fig. 2

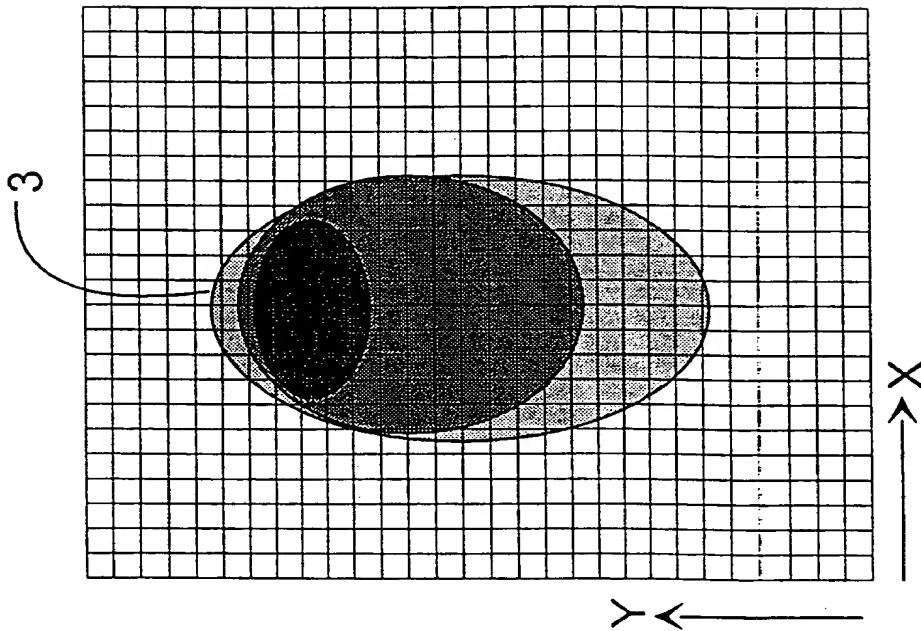


Fig. 3a

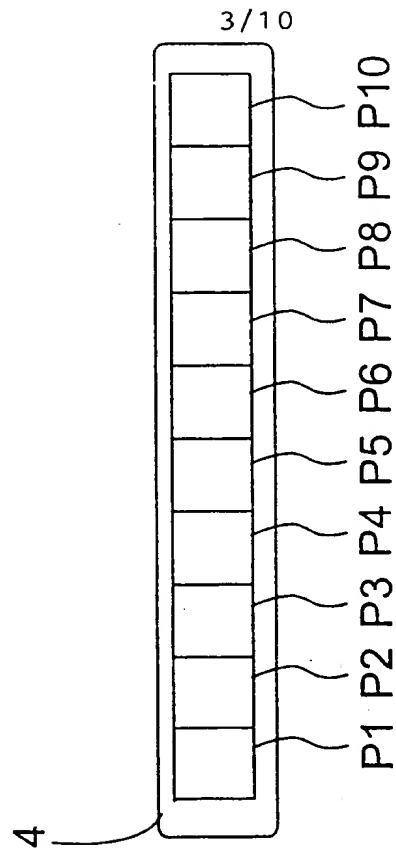


Fig. 3b

Fig. 3c

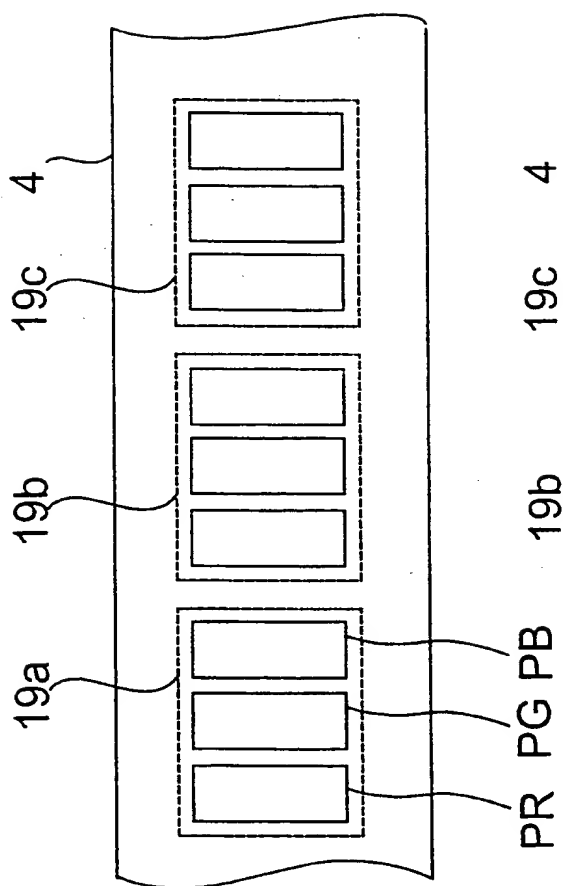
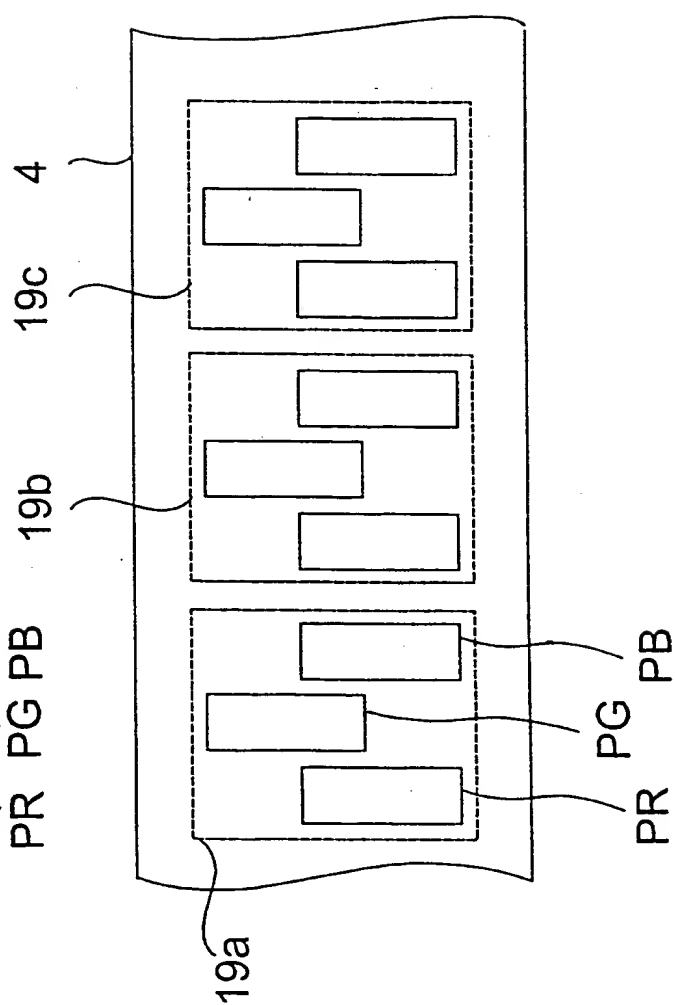


Fig. 3d



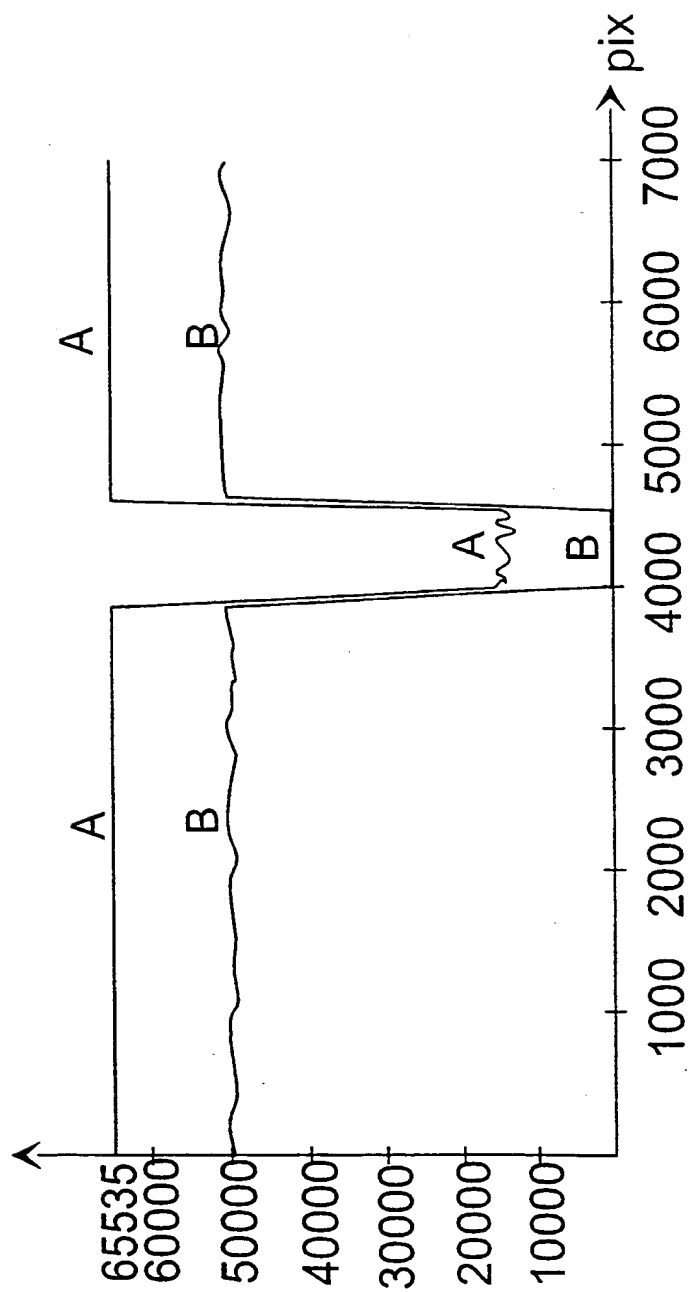


Fig. 3e

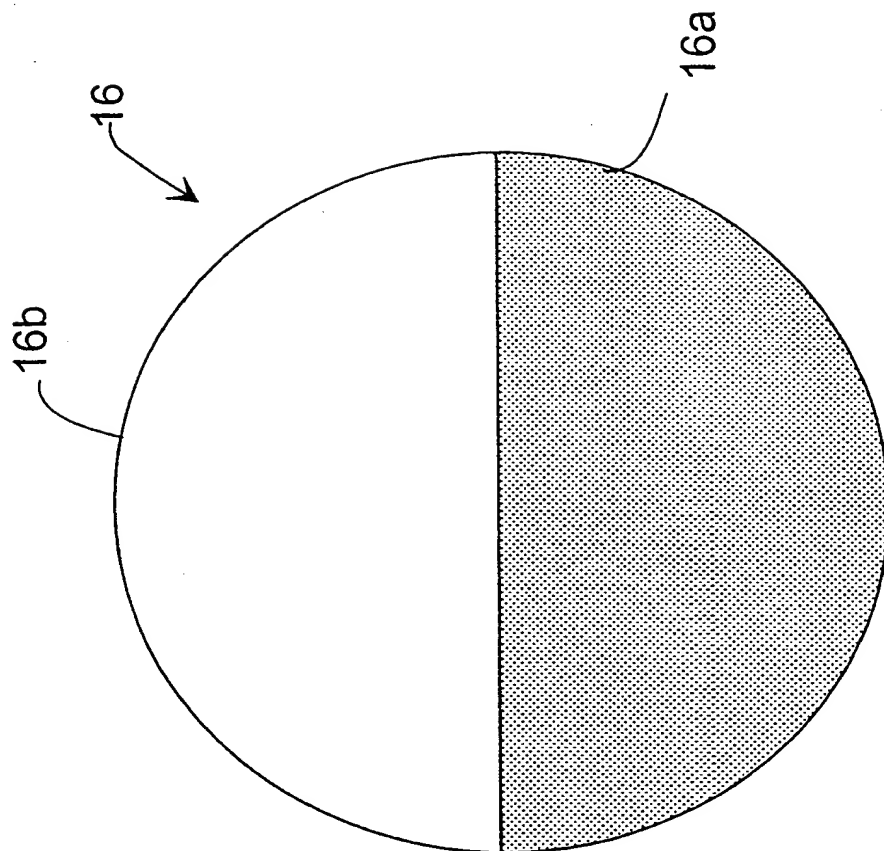


Fig. 4

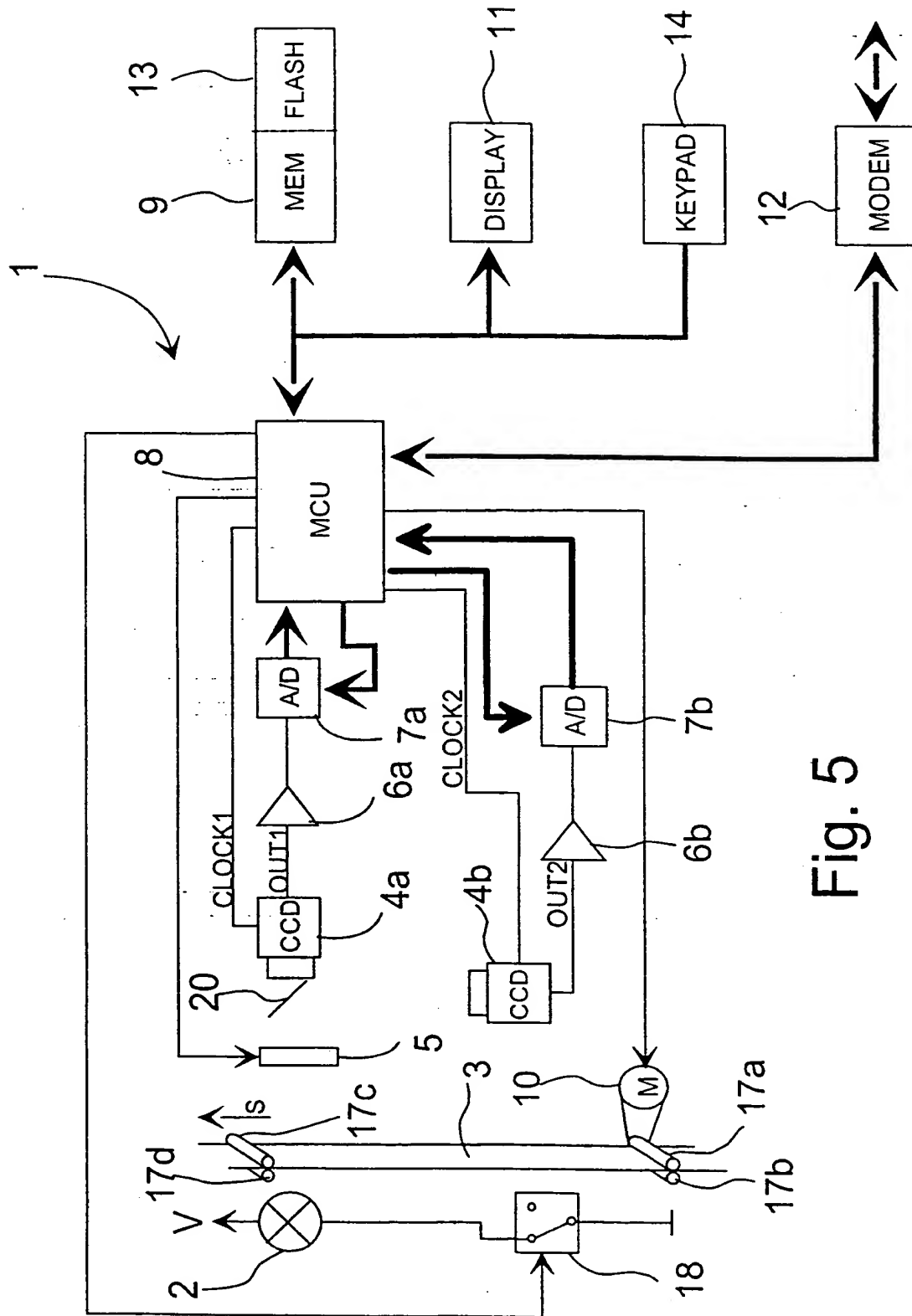


Fig. 5

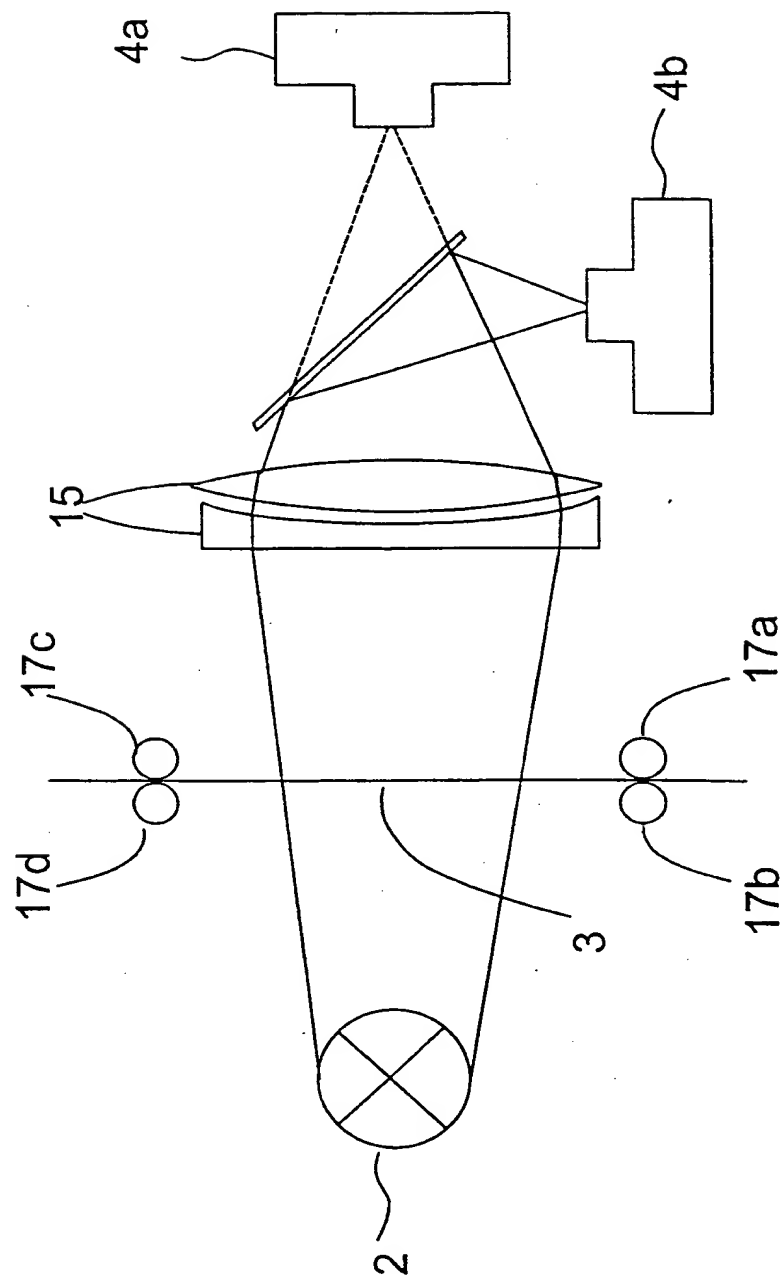


Fig. 6

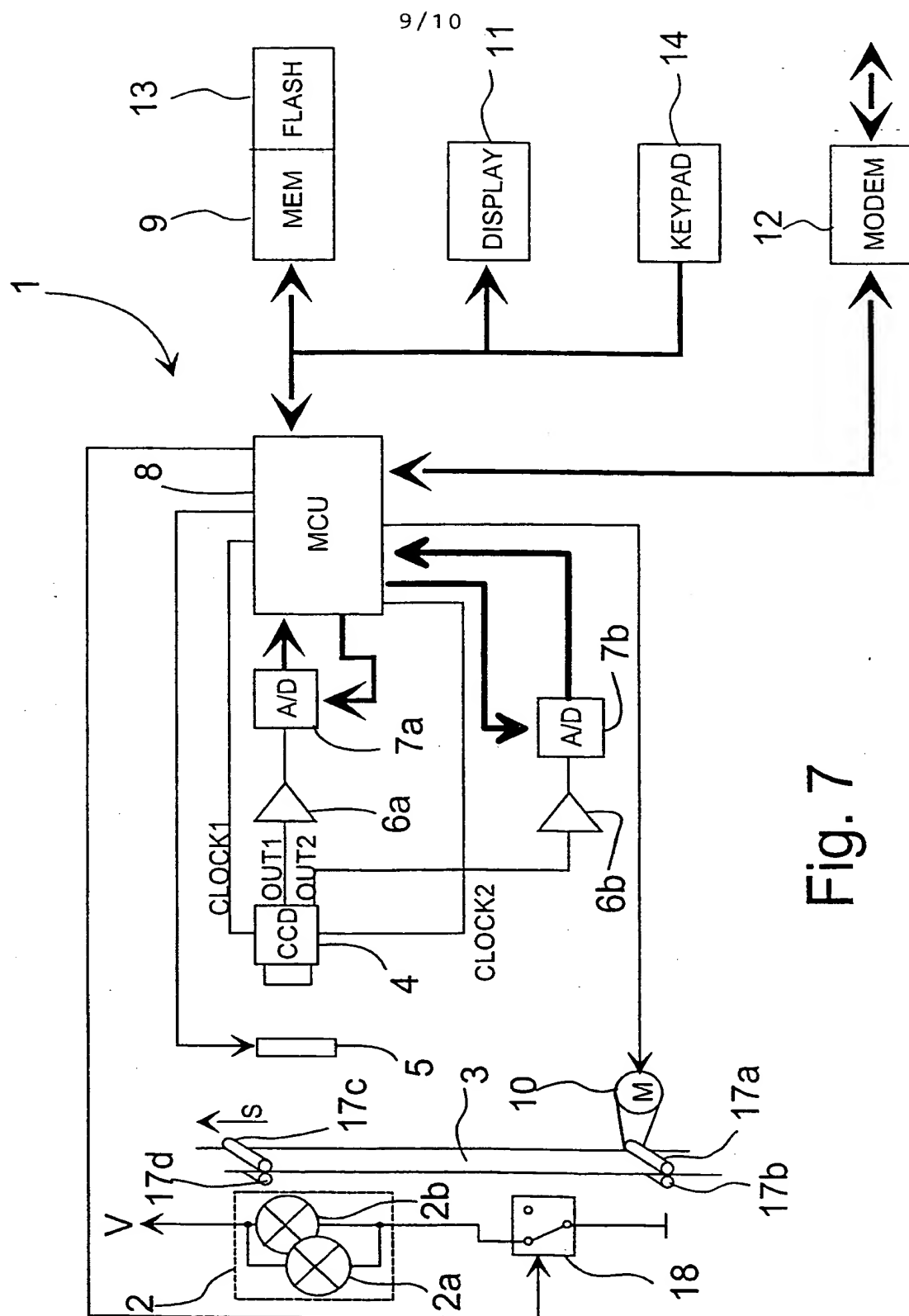


Fig. 7

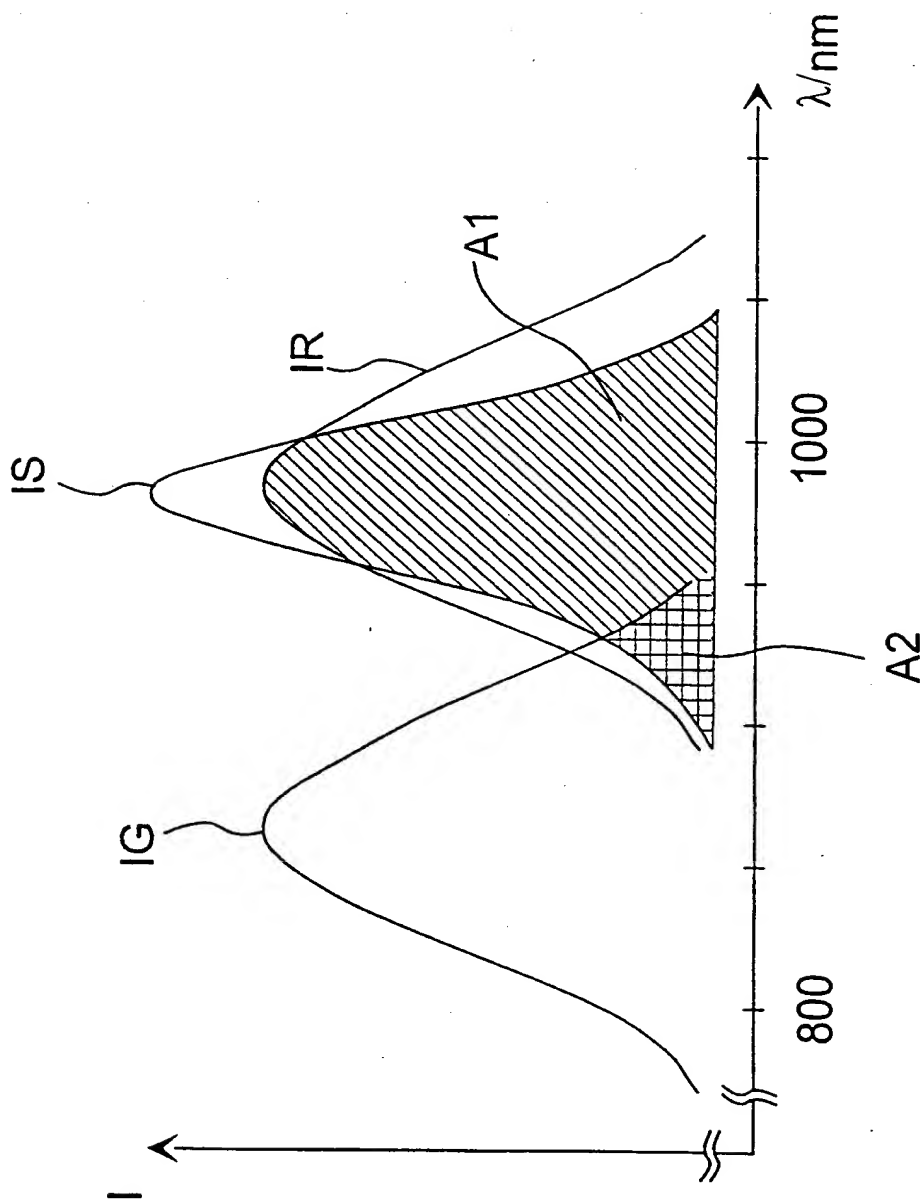


Fig. 8

# INTERNATIONAL SEARCH REPORT

International application No.

PCT/FI 98/00510

## A. CLASSIFICATION OF SUBJECT MATTER

IPC6: H04N 5/235, H04N 5/32 // G01T 1/29, H04N 3/15

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC6: H04N

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 4584606 A (TATSUO NAGASAKI), 22 April 1986 (22.04.86), figures 3,10, abstract	1-4,7-8, 13-17
Y	--	5-6,9-12
Y	WO 9418801 A1 (I SIGHT, INC.), 18 August 1994 (18.08.94), page 4, line 11 - page 8, line 18, figure 1, abstract	5-6,9-12
A	US 5221848 A (JAMES R. MILCH), 22 June 1993 (22.06.93), column 2, line 9 - line 52, abstract	1,14
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☒ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

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# INTERNATIONAL SEARCH REPORT

International application No.  
PCT/FI 98/00510

## C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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